VOLUME 81 SEPARATE No. 610

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

FEBRUARY, 1955

CHANNEL DEPTHS FOR MODERN PORTS

by B. B. Talley, M. ASCE

WATERWAYS DIVISION

{Discussions open until June 1, 1955}

Copyright 1955 by the AMERICAN SOCIETY OF CIVIL ENGINEERS
Printed in the United States of America

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

PRICE $0.5

THIS PAPER

--represents an effort by the Society to deliver technical data direct from the author to the reader with the greatest possible speed. To this end, it has had none of the usual editing required in more formal publication procedures.

Readers are invited to submit discussion applying to current papers. For this paper the final date on which a discussion should reach the Manager of Technical Publications appears on the front cover.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying "Publication Procedure for Technical Papers" (Proceedings – Separate No. 290). For free copies of this Separate—describing style, content, and format—address the Manager, Technical Publications, ASCE.

Reprints from this publication may be made on condition that the full title of paper, name of author, page reference, and date of publication by the Society are given.

The Society is not responsible for any statement made or opinion expressed in its publications.

This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

$0.50 PER COPY

CHANNEL DEPTHS FOR MODERN PORTS

B. B. Talley,[1] M. ASCE

SYNOPSIS

Primary considerations in determining depths to be provided in a modern harbor are the drafts of the vessels expected to use the port, the customary trim or loading of ships, the "squat" or "sinkage" of vessels in motion under their own power, the nature of the material in which a channel lies and the clearance under keels. Additional depth is usually required in exposed entrance channels to provide clearance for ships while pitching during storms. The trend in design respecting draft is indicated by data on typical vessels of various classes constructed during this century. Specific figures for channel depths are presented.

The Federal Government has been instrumental in improving the Nation's rivers and harbors for navigation for 130 years. Federal activity is evidenced by: the provision of funds for investigations and surveys of navigation improvements, requested by the public; the authorization as Federal projects of such works as are found to be engineeringly sound and economically feasible; and, finally, the appropriation of funds for construction of the authorized works.

The Congressional authorization is predicated primarily on the recommendations of the Chief of Engineers, U.S. Army, who formulates his views and recommendations on the results of investigations by the Corps of Engineers.

Basically, a favorable recommendation requires that the estimated benefits to whomsoever they may accrue, appraised on a monetary basis, shall equal or exceed the annual cost of the improvement including interest, amortization, maintenance and operation. Therefore, the engineers in the Corps are continually confronted with the question of the desirable and feasible depths to be provided in channels in modern ports.

In some harbors, the needs of national defense prescribe the appropriate depths of channels and other economic justification is not essential. However, this paper is concerned only with the requirements of commercial shipping excluding inland waterways.

For convenience of reference, vessels utilized in this activity may conveniently be classified under four general headings, namely: (1) Large Passenger, (2) Combination Passenger and Cargo, (3) General-Cargo, and (4) Bulk-Cargo Vessels. The depths of water required by these various classes are discussed herein, taking into consideration the draft of such ships, now in operation, and the general trend in design respecting draft.

Experience indicates that a general increase in design draft usually precedes any enlargement in channel dimensions. This is natural when the trend in marine construction is toward larger carrying capacity, because, in the design stage, the economical way to obtain greater capacity is to increase

1. Colonel, Corps of Engineers, U.S. Army, Division Engineer, North Atlantic Division, New York, N.Y.

the shortest dimension of a ship which is its depth. As a result of this practice, drafts of ships become greater than harbor depths, requiring such vessels to lose time at anchor waiting for favorable tides, or to lighten cargo before transiting the harbor channels. This situation results in economic losses which, on an annual monetary basis, are frequently greater than the cost of deepening the waterways. Thus it is that projects for the deepening of harbor channels have their inception.

In large harbors, there are usually several channels with varying depths, depending on the nature of the commerce which utilizes the particular channel. For example, in New York Harbor the main channel in the Lower and Upper Bays and in Hudson River to 59th Street is deep enough to accommodate the largest passenger liners, whereas the depths available in the New York and New Jersey Channels leading to the oil docks on Arthur Kill between Staten Island and the New Jersey mainland are substantially less—the project depth in these channels being influenced by the requirements of the oil industry.

Thus: It should be recognized that the primary consideration in establishing channel depths is the draft of shipping expected to use the waterway. To this draft of ships must be added a depth of water under the keel sufficient to assure safe operation of a ship, moving under its own power. For safe operation, clearance under the keel will vary according to the size of the ship and, in some channels, the speed of the ship must be considered. A minimum clearance of two feet has usually been provided in the past. To this clearance must be added the change in level of a vessel when moving through water and referred to as "squat" or "sinkage." Vessel "squat" becomes greater as the speed increases. This fact becomes important in long channels such as the Delaware River where higher speeds are permitted than in inner harbor channels; and where they are required for economical operation. As most harbors are transited at reduced speed an allowance of from 2 to 3 feet additional depth for "squat" is desirable and adequate.

Theoretically a vessel should be loaded to even keel to obtain its maximum capacity for cargo. However, this loading usually results in a vessel becoming bow heavy under operating conditions, therefore it is usually trimmed to utilize an additional one or two feet of water at the stern.

The effect of loss in buoyancy between salt and fresh water may properly be considered in certain channels but such loss usually is less than one foot.

The authorized depth of water in a channel is referred to a datum plane of mean low water at ports on the Atlantic and Gulf coasts and mean lower low water at ports on the Pacific coast. Therefore, there is an additional depth available, over that authorized, as the tide floods.

In early days the drafts of ocean-going vessels were limited by the natural depth of water available over the bars at the entrance to seaports. The development of hopper dredges, early in this century, which could function on these bars and provide deep entrance channels had a remarkable effect on the design of ships. Prior to the advent of these dredges, there were but few ships which drew over 23 feet of water. Subsequent to this time, drafts have increased to the extent that 25 to 30 feet are common and some of the larger vessels draw from 35 to 40 feet. Of passing interest is the fact that the GREAT EASTERN, built about 95 years ago, had a draft of 26 feet.

The largest passenger ships requiring the deepest channels have been built in foreign countries. A vessel of historical importance was the LUSITANIA, built about 1907, which had a draft of 36 feet. The ill-fated TITANIC, about five years later, had a draft of 34 1/2 feet. The LEVIATHAN, built in Germany in 1914, was a mammoth ship for those days having a length of 950 feet and gross tonnage of 54,000. Its draft was 39 1/2 feet. One of its

competitors, put in commission about the same time but under the English flag, was the AQUITANIA which had a gross tonnage of nearly 46,000 and draft of 35' -4". One of the large early ships flying the French flag is the ILE DE FRANCE constructed in 1926 and reconstructed in 1949. It is a 45,000-ton ship and now draws 34 feet of water. This ship might be contrasted with another French liner, the NORMANDIE, one of the great ships of history, built in 1935 with a gross tonnage of 82,800 and draft of 36' -7". The English competitors of the NORMANDIE were the two Queens, MARY and ELIZABETH, whose lengths, breadths and gross tonnages are approximately the same as were those of the NORMANDIE but whose drafts are greater, being approximately 39 1/2 feet.

The foregoing statistics are presented to show that, during the entire first half of this century, great foreign-built passenger ships with drafts between 35 and 40 feet have been in the transatlantic service between the United States and a limited number of British, French and North Sea ports where the necessary depth of water is available. The customary United States terminal for these ships is New York where a channel depth of 45 feet has been provided from the ocean, through the Lower and Upper Bays and the Hudson River Channel to 59th Street.

It is unlikely that passenger ships with greater draft will be constructed in the foreseeable future and the existing depth in New York Harbor is considered to be adequate for this class of vessel.

The foregoing data have been limited to foreign ships. The reason for this is that the trend in design of large passenger ships built in this country over the last 25 years is toward increase in length and breadth with no relative increase in draft. The AMERICA, built in 1940 with a draft of 32' -6", was the largest domestic passenger ship until the construction of the UNITED STATES in 1951. The gross tonnage of the latter ship (about 53,000) is double that of the AMERICA but the drafts do not vary greatly. The large increase in tonnage was accomplished by an increase in length of vessel from 723 feet to 990 feet, and in breadth, from 93' -3" to 101' -6". The relatively small draft of large American passenger ships makes it possible for them to call at a wider range of ports.

There are currently under operation, intermediate-size passenger ships capable of calling at many world ports. The depth of channel in a modern harbor suitable for this service merits comment. An example of this class of vessel is the LURLINE, constructed in 1932, which operates from a Pacific coast port. Its length is 631 feet; breadth, 82 feet; and gross tonnage, about 18,500. Of particular interest in this discussion is its draft of slightly more than 28 feet, which is substantially less than the depth provided in most United States ports. Other examples of passenger vessels of intermediate-size are the CONSTITUTION and INDEPENDENCE constructed in the United States within the last five years for the New York-Mediterranean service. These vessels are nearly 700 feet long and have gross tonnages of about 24,000 and drafts of about 30 feet.

The draft of such intermediate-size passenger vessels is not expected to increase in an important amount in the foreseeable future and a 36-foot depth of channel in modern harbors is considered to be adequate for this type of service.

Combination passenger and cargo vessels call at many ports throughout the world. Typical ships constructed early in this century such as the BRAZOS (1907), COAMO (1925) and COLUMBIA (1932) had lengths between 400 and 500 feet and drafts from 22 to 25 feet. The gross tonnage of these vessels varied from 5000 to 7000. Prior to World War II there was no distinct trend toward

greater capacity. Since that time, the Maritime Administration vessels, within the same range of length, have shown a tendency toward increased size and greater draft. Standard C-2 and C-3 type ships, discussed in the following paragraph, have been modified into combination passenger and cargo ships and drafts are generally in the range of 26 1/2 to 28 1/2 feet. This trend toward greater draft may continue but 30 feet is thought, at present, to be a reasonable limit. Therefore it may be desirable, within the foreseeable future, to provide a channel depth of 35 feet in harbors frequented by this type of vessel.

For the last 15 years the Federal Government has been the largest builder of general cargo vessels. During World War II, the United States Maritime Administration had in force three separate programs of construction. The C-1, C-2 and C-3 type vessels were products of a long-range peacetime program. The Liberty and Victory-ship programs were war-time expedients only; the prototypes of these vessels being the C-2 type ship. The deadweight tonnage of the standard C-2 ship is 10,775 and the draft, 27'-7"; corresponding figures for the C-3 type are 12,300 and 28'-6" respectively. More recently the Administration has produced the Mariner class of cargo vessel.

The Mariner class of vessel has a capacity of about 13,400 deadweight tons, which is an increase of 24% over the C-2 ship and 9% over the C-3 type. However, this increase was accomplished primarily by greater length and beam, since the draft of the Mariner type is only about 30 feet. Because of its increased capacity and speed (20 knots) this type of vessel will become important in world commerce and it is concluded that modern harbors which are ports of call for general cargo vessels will need a channel depth of at least 35 feet in the foreseeable future.

There is a distinct trend toward greater capacity in the design of ocean-going bulk-cargo vessels. In the case of ore carriers prior to this year, the increase has been accomplished by greater length and breadth with little change in draft while, in the case of tankers, the draft has also increased. The reason for this difference in design respecting draft merits some explanation. Some 32 years ago the draft of ore carriers of about 23,000 deadweight tons, plying between Chili and Baltimore, Md., was about 34 feet. In 1945, the Venore-class ship of about 24,400 deadweight tons entered this service. Thus the capacity was increased but the draft of the new ships is only about three inches greater than that of the older ships. The distinctive feature of the new ships was an increase in speed from 11 knots to 16 1/2 knots. The design draft of ore carriers has been dictated for many years by the available depths in channels transited by the carriers. A notable change in size of ships has taken place this year. Two ore carriers have been put into service, and a third is scheduled for the end of this year, which have an overall length of 794 feet; beam, 116 feet; and draft, 38'-6". The capacity of these ships when loaded with iron ore at this draft is about 60,700 deadweight tons or about 60,000 tons of ore. One of the proposed American terminals of these new ships is the Fairless Works of the United States Steel Company on the Delaware River at Morrisville, Pa. In anticipation of the large volume of commerce expected, including iron ore, and the size of the ships in which a large part of it will move, Congress, at its last session, authorized a channel depth of 42 feet in rock and 40 feet in other material extending from Newbold Island near Morrisville to the Philadelphia Naval Base where a 40-foot depth is now available.

The history of the tanker is different from that of the ore carrier. At the time of World War I, the U. S. Shipping Board was building tankers having a length of 445 feet and a draft of 25 1/2 feet. During World War II, the T-2

tankers of the U. S. Maritime Administration had lengths between 500 and 525 feet, deadweight tonnages between 16,000 and 17,000 and drafts of slightly less than 30 feet or 4 1/2 feet greater than the Shipping Board tankers. By about 1950, several oil companies had put tankers in service with drafts of about 34 feet, equal to that of the ore carriers of that time, but with greater breadth and length (over 650 feet) resulting in a deadweight tonnage of about 30,000. This spectacular increase in size of tanker has continued to the present day. A 45,500-ton tanker, WORLD GLORY, was recently put in service and other vessels of about equal size are under construction. The WORLD GLORY is about 736 feet in length, being longer than the CONSTITUTION and INDEPENDENCE and slightly longer than the AMERICA. Its draft is about 37 1/2 feet which perhaps is the result of a look into the future because few if any channels in this country which are provided primarily for the oil industry have sufficient depth for such a vessel, when fully loaded. A common practice in the past has been to provide a project depth of 35 feet in salt water and 36 feet in fresh water for the transportation of petroleum and its products. Tankers comparable to the WORLD GLORY would require at least a 40-foot depth of channel. For the present at least, it is expected that such tankers will be used to transport crude oil from Persian Gulf points, Venezuela, and other large foreign shipping centers, to a limited number of the larger ports in this country where oil docks are or can be located on main channels, which already have the necessary depth because of the requirements of other classes of shipping.

Summarizing the foregoing, the modern harbor should have channel depths consistent with the requirements of the commerce of the port. For the largest passenger ships a depth of 45 feet is considered satisfactory now and for the foreseeable future with a slightly greater depth for turning. For the intermediate-size passenger ship, 36 feet should be adequate. The combination passenger and cargo vessels need about 33 feet at the present time and will probably require a 35-foot channel in the foreseeable future. The desirable depth for the general cargo vessel of the future is 35 feet. At least a 40-foot channel is required in some harbors for the large ore carriers and the trans-ocean crude-oil-carrying tankers just coming into being. Depths of 35 to 36 feet, found in many channels in the United States utilized principally by tankers transporting petroleum products are considered adequate for those harbors which are not likely to be ports of call for the large trans-ocean crude-oil carriers.

It should be borne in mind that the desirable depth of channel in a modern port is not always susceptible of attainment from an economic point of view. Those responsible for the development must consider a proposed harbor improvement project both from an engineering and economic standpoint. As a result, a tabulation of channel dimensions in United States ports will indicate deviations from the views expressed herein and variations between ports which cannot be explained by the character of the commerce.

The foregoing discussion has been limited to inner channels in protected harbors. The desirable depth to be provided in the entrance channel to an exposed seaport is dependent not only on the draft of vessels frequenting the port but also on other factors. No definite relationship exists between the depths of entrance and inner channels as provided by the Federal Government except that the former equals or exceeds the latter. Factors requiring consideration include the exposure to wind and wave, the character of the material in which the channel lies and the general slope of the ocean bottom. Some examples of depths of entrance channel designed as a result of experience may be of interest. The principal entrance to New York Harbor is Ambrose

Channel. It crosses the shoals between the Atlantic Ocean and the Lower Bay. Beyond the shoals lies the continental shelf which slopes gently to ocean depths. The material comprising the shoals and shelf is soft. Thus nature has provided conditions which reduce the effect of wave action, the pitching of vessels, and the amount of damage to a vessel's hull in the event of contact with the channel bottom or sides. These favorable conditions have made it practicable to limit the depth of the entrance channel to 45 feet which is no greater than the Anchorage Channel in the Upper Bay and lower Hudson River Channel to 59th Street. Similarly, in Boston, the inner channel depth is 40 feet which is the depth of that portion of the entrance channel which lies in soft material. That portion of the entrance channel which lies in rock is 45 feet deep, or five feet greater than in channels in soft material. Here we find an example of the effect of a hard bottom on design depths.

The depth of entrance channel to Hampton Roads in Virginia is 40 feet which is the same as the inner channels leading to Newport News, James River, Norfolk and Portsmouth. Here again the channel lies in soft material and is long before reaching ocean depths, thus producing conditions which reduce the pitching of vessels.

In contrast to these eastern ports are conditions existing at San Francisco, California and at the mouth of the Columbia River, Washington and Oregon. There are ocean bars outside the Golden Gate and opposite the Columbia River which must be crossed through artificial channels. The contour of the ocean bottom and exposure to the elements are such that great pitching of vessels is common during storms. As a result, the authorized depth across the bar near Golden Gate is 50 feet although no artificial channel in the Bay area is over 40 feet deep. It is true that natural depths in San Francisco Bay are generally in excess of the requirements of navigation. The depth of the navigation channel in the lower Columbia River is 35 feet. The depth across the ocean bar has been 40 feet for many years. However, this latter depth has been found to be inadequate and, during the last session of Congress, a depth of 48 feet across the bar was authorized.

The conclusion to be drawn from the foregoing discussion is that the desirable depth of entrance channel to a modern seaport should be based on the depth provided on inner harbor channels, and, in addition, on conditions which obtain at each individual site with particular reference to the character and extent of commerce to be expected, the exposure to the elements as reflected by wind and wave action and currents, the slope of ocean bottom and length of channel, material comprising the bottom and sides of the channel and the history of the effect of existing conditions on the pitching of vessels during storms.